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REMEDIAL ACTION OBJECTIVES AND REMEDIAL ALTERNATIVES OPERABLE UNIT NO. 3 216 PATERSON PLANK ROAD SITE CARLSTADT, NEW JERSEY

Prepared for:

216 Paterson Plank Road Cooperating PRP Group

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1.0 INTRODUCTION

This Remedial Action Objectives and Remedial Alternatives Report (Report) has been prepared by Golder Associates Inc. (Golder) on behalf of the 216 Paterson Plank Road Cooperating PRP Group (the Group). This Report is an interim deliverable as part of the Feasibility Study (FS) for Operable Unit 3 (OU-3) of the 216 Paterson Plank Road Site[1] (Site). The Report identifies preliminary remedial action objectives, and presents an evaluation of potential remedial technologies leading to a range of remedial action alternatives that will be further evaluated in the final FS.

OU-3 addresses Site-related impacts to deep groundwater in the glacial deposits and bedrock, which has been the subject of extensive investigations as described herein and in the Off-Property Investigation Report submitted to USEPA in September 2007. OU-3 is the final operable unit for the Site and follows interim measures implemented under OU-1, and the final remedy for soils and shallow groundwater addressed as OU-2. As such, the OU-3 remedy will compliment the source control and treatment measures included as part of OU-1 and OU-2 so as to achieve the Site-wide remedial action objectives.

This Report provides an initial evaluation and refinement of the preliminary list of remedial alternatives provided to USEPA in Golder Associates e-mail dated February 18, 2008, and also addresses USEPA's comments on the preliminary alternatives conveyed by a Region 2 e-mail dated March 11, 2008.

[1] The Site is also sometimes referred to as the former Scientific Chemical Processing Site or SCP Site. The Site includes the property located at 216 Paterson Plank Road (i.e., on-property area) and related off-property groundwater impacts.

2.0 BACKGROUND

2.1 Description of Property

The 6-acre property is a former chemical recycling and waste processing facility, which ceased operation in 1980, and is located in a light industrial/commercial area of Carlstadt, New Jersey. The property is bordered to the southwest by Paterson Plank Road, to the northwest by Gotham Parkway, to the southeast by a trucking company, and to the northeast by Peach Island Creek. The Site was placed on USEPA's National Priorities List (NPL) in 1983.

2.2 Operable Unit No. 1

A Remedial Investigation (Dames and Moore, 1990) was initiated in 1987, which evaluated soil and groundwater contamination beneath the Site. In broad terms, the investigation revealed ground conditions comprised of fill overlying a clay layer, which was in turn underlain by glacial till and bedrock. Between 1987 and 1988, fourteen shallow piezometers (P-1 to P-14), and 7 shallow monitoring wells (MW-1S to MW-7S), were installed in the fill zone, along with three (3) deeper monitoring wells in the glacial till (MW-2D, MW-5D, and MW-7D).

An initial Feasibility Study was conducted in 1989 (ERM, 1989) to evaluate remedial alternatives for the shallow groundwater and soils (fill) above the clay layer.

Nine additional monitoring wells were installed off-property by Dames and Moore in 1989, pursuant to Project Operations Plan (POP) No. 8 (Dames and Moore, 1988A). Five shallow monitoring wells were screened within the fill (MW-8S to MW-12S) and four deeper monitoring wells were installed in the glacial till (MW-8D, MW-11D, MW-12D, and MW-13D). At the specific request of one of the off-property owners, and with the approval of USEPA, monitoring well RMW-13D was subsequently installed in October 1995 as a replacement for MW-13D. Following two rounds of comparative groundwater sampling in RMW-13D and MW-13D, monitoring well MW-13D was decommissioned with the approval of USEPA.

A deep bedrock monitoring well (MW-2R) was installed on the property by Dames and Moore in 1989 pursuant to POP No. 9 (Dames and Moore, 1988B). Dames and Moore also excavated 23 test pits in July, 1989 to further evaluate the nature of the fill material. The results are summarized in a report titled Final Report - Excavation of Test Pits (Dames and Moore, 1989).

A Baseline Risk Assessment (BRA) for the Site was conducted by Clement Associates (Clement, 1990) for the USEPA. The BRA followed USEPA guidance for conducting risk assessments current at the time and was based primarily on information collected during the initial phase of the RI.

USEPA issued a Record of Decision (ROD) dated September 14, 1990, selecting an interim remedy for OU-1, based on the Remedial Investigation, Feasibility Study, and the BRA. The ROD defined OU-1 as “contaminated soils and groundwater above the clay layer”. USEPA determined that the selected Interim Remedy would “reduce the migration of hazardous substances, pollutants and contaminants out of the first operable unit zone” and be “consistent with an overall remedy which will attain the statutory requirement for protectiveness.”

The Interim Remedy was designed and implemented by the Group pursuant to an Administrative Order (Index No. II CERCLA - 00116) dated September 28, 1990. The Interim Remedy consists of the following:

1. A lateral containment wall comprising a soil-bentonite slurry wall with an integral high density polyethylene (HDPE) vertical membrane, which circumscribes the property;

2. A horizontal "infiltration barrier" consisting of high density polyethylene (HDPE) covering the property;

3. A sheet pile retaining wall along Peach Island Creek;

4. A groundwater extraction system for shallow groundwater consisting of 5 extraction wells screened in the fill, which discharge to an above grade 10,000 gallon holding tank via an above grade header system; and,

5. A chain link fence that circumscribes the Property.

The design of the Interim Remedy is presented in the Interim Remedy Remedial Design Report (Canonie, 1991) and construction was undertaken between August, 1991 and June, 1992.

The Interim Remedy has been in operation since June 1992 and extracted groundwater is regularly shipped, via tanker trucks, to the DuPont Environmental Treatment (DET) facility, located in Deepwater, New Jersey, for treatment and disposal. Maintenance and monitoring of the Interim Remedy are conducted pursuant to the USEPA-approved Operations and Maintenance Plan (Canonie, 1991) and subsequent addenda approved by USEPA. The regular monitoring program currently consists of eleven groundwater monitoring wells (MW-5D, MW-7D, MW-8SR, MW-8D, MW-9S, MW-10S, MW-11SR, MW-11D, MW-12SR, MW-12D, and RMW-13D) and four surface water sampling points in Peach Island Creek. In accordance with correspondence from USEPA dated June 30, 1995, surface water samples are analyzed for Target Compound List (TCL) volatile organic compounds (VOCs) quarterly, and groundwater samples are analyzed for the full Target Analyte List (TAL) and TCL compounds annually.

2.3 Operable Unit No. 2

At the request of USEPA, a Focused Feasibility Study (FFS) was conducted by Golder Associates for the final remedial action for the fill and shallow groundwater. The work was conducted pursuant to an approved Focused Feasibility Study Work Plan (Golder Associates, 1995). The FFS also included an investigation of a distinct sludge area within the fill zone, which was presented in the Focused Feasibility Study Investigation Report (Golder Associates, 1997A) and a treatability study of the sludge materials pursuant to a Treatability Study Work Plan (Golder Associates, 1998). The FFS was finalized in April 2001 leading to USEPA's selection of a final remedy for the fill and shallow groundwater, referred to as Operable Unit 2 (OU-2), in August 2002.

USEPA's Record of Decision (ROD) dated August 12, 2002, selected the following final remedy for the fill and shallow groundwater:

- In-situ air stripping of a sludge "Hot Spot" area and collection and on-Site treatment of removed VOCs;
- In-situ stabilization of the sludge "Hot Spot" utilizing a cement-lime mixture;
- Installation of a final cap over the area circumscribed by the existing slurry wall;
- Upgrading/replacement of the existing shallow groundwater collection system, including installation of new wells and below grade headers in clean utility corridors;
- Upgrading/replacement of the existing sheet pile wall along Peach Island Creek;
- Institutional Controls in the form of a Deed Notice on the property to protect the remedy and preclude inappropriate future land use.

A Consent Decree dated September 30, 2004 was executed between USEPA and the Group for the design and implementation of the OU-2 remedy. The Final Design was approved by USEPA in May 2007, and the remedy is currently under construction with completion targeted for early 2009.

2.4 Operable Unit No. 3

2.4.1 Summary of Off-Property Groundwater Investigations

Further Off-Property investigation was conducted between June and September, 1996 pursuant to an approved work plan (Golder Associates, 1995). The work included installation of six (6) till monitoring wells MW-10D, MW-14D, MW-15D, MW-16D, MW-17D, and MW-18D (see Figure 1) and bedrock monitoring wells MW-8R, MW-10R, MW-11R, and MW-14R (see Figure 2) as summarized in the Interim Data Report (Golder Associates, 1997B). Additional investigation was conducted in August and September, 1998 as requested by USEPA and summarized in Golder Associates' letter dated February 13, 1998. This involved installation of several replacement monitoring wells[2] (RMW-8D, RMW-11D, and RMW-12D) to address deterioration of seals in previous wells, which were decommissioned, and several additional off-property wells (MW-13R, MW-19D, MW-20D, MW-20R and MW-21D). The results of this investigation were summarized at a meeting on March 17, 1999. Additional investigations were subsequently conducted in 2002 consisting of the installation of additional wells MW-15R, MW-19R, MW-22D and MW-23R. The results of all of this investigation were presented in the Off-Property Groundwater Investigation Report (Golder Associates, 2003).

An addendum to the 2003 report was submitted in June 2005 in response to USEPA comments dated December 2004, which requested additional investigation to further define the nature and extent of groundwater contamination in till and bedrock. The scope of the additional investigation was agreed to at a meeting with USEPA on November 29, 2006 as documented in a letter dated January 9, 2007 from Golder Associates.

The associated field work was carried out between March and July 2007 and consisted of the installation of monitoring wells MW-24D, MW-24R, MW-25D, MW-25R, MW-26D, MW-27R and MW-28R. The results of this investigation were submitted, together with summaries of all previous investigations, in the Off-Property Groundwater Investigation Report dated September 2007.

[2] Replacement wells are designated by the prefix "R".

2.4.2 Off-Property Groundwater Investigation Results

The OU-3 groundwater investigations have revealed that the geologic conditions both on- and off-Property comprise the following units from top to bottom:

- Man made fill (3-10 feet thick);
- Marine and marsh "meadow mat" (0-4 feet thick);
- Glaciolacustrine varved clay unit, including an upper stiff bedded unit and a lower soft plastic clayey unit (0-20 feet thick);
- Glacial till, including a soft upper unit (0-17 feet thick) and an overconsolidated lower lodgement till (0-30 feet thick); and,
- Passaic Formation bedrock consisting of siltstones and mudstones with occasional interbeds of sandstones.

Groundwater flow directions in the till and bedrock have been investigated using data logging and shown to be variable and strongly influenced by intermittent (weekday) pumping in the area and, to a lesser degree, by tidal fluctuations. Hydraulic gradients within the till are predominantly downward, and vertical hydraulic gradients in the deep bedrock are upward. The average horizontal linear flow velocity in the till and bedrock are low; for example, calculated velocities in the bedrock range from 3.1 to 7.2 ft/year.

Based on the estimated horizontal groundwater flow velocities, the monitoring well network established in connection with the Site extends beyond the maximum anticipated travel distance of contaminants from the Property since operations began, conservatively ignoring any contaminant retardation. As such, the present monitoring well network is expected, at a minimum, to address all of the Site-related contamination present. The contaminants of concern (COCs) on-Site include chlorinated aliphatic hydrocarbons (CAHs), consisting predominantly of chloroethenes (tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE) and vinyl chloride); limited chloroethanes; and localized aromatic hydrocarbons, predominantly benzene, toluene, ethylbenzene and xylenes, known collectively as BTEX. Figures 1 and 2 summarize the groundwater quality data for the till and bedrock units, respectively. BTEX impacts are localized to the south corner of the Property where two wells also show impacts from 1,4-dioxane[3].

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[3] 1,4-dioxane is an emerging contaminant of concern to USEPA and was included in the most recent sampling round at the Agency's request.

Concentrations of VOCs decrease substantially with increasing horizontal and vertical distance from the property. The highest level of VOCs in the bedrock wells are detected in MW-13R (560 ug/L of total VOCs) located adjacent to the northwest corner of the property, but these concentrations decline to trace levels within 600 to 1,000 feet horizontally (see Figure 4). Concentrations also decline vertically, with only trace VOC levels detected in MW-23R located adjacent to but deeper than MW-13R. Similarly, the highest levels of VOCs in the till wells are also located in the northwest corner of the property in MW-5D (6,281 ug/L of total VOCs). These concentrations decline to 51 ug/L in MW-25D approximately 1,000 feet to the northwest and 5 ug/L in MW-26D located approximately 950 feet to the north (see Figure 3).

Till monitoring well MW-21D, located closest to the southern corner of the property margin (i.e., generally upgradient), contains elevated levels of benzene, 1,1-dichloroethane, and 1,4 dioxane. This "signature" is distinct to this area of the Site with these compounds sporadically detected only at much lower concentrations in other till and bedrock monitoring wells, including adjacent well MW-22D[4]. Accordingly, this contamination may be highly localized.

2.4.3 Summary of Natural Attenuation Parameters

The current concentrations of nearly all VOCs are below historic high concentrations, and in many cases substantially below, which is believed to be the result of natural attenuation processes. Concentrations also generally decrease substantially with increasing horizontal and vertical distance from the Property. At some monitoring wells, the biodegradation processes have been successful in fully reducing chlorinated compounds to their ultimate non-toxic daughter products (ethene, ethane, and methane). Based on concentration trend analyses presented in the 2007 OU-3 Groundwater Investigation Report (Golder, 2007) it is concluded that:

1. Chlorinated ethene contamination has declined in almost all till and bedrock wells and there is strong evidence of complete natural degradation to non-toxic end-product ethene.
2. Chlorinated ethanes and methanes show trends similar to those for chlorinated ethenes.
3. BTEX compounds are also generally at low levels (typically ND) in all wells, other than MW-21D.

[4] 1,4-dioxane alone is detected in MW-22D but at significantly lower concentrations than the adjacent MW-21D.

The evidence of natural attenuation processes provided by sharply reduced contaminant concentrations is further substantiated by geochemical data that suggests that many wells exhibit conditions that are conducive to anaerobic biodegradation of COCs. One (1) well in particular, MW-21D, shows exceptionally strong evidence for anaerobic biodegradation. The presence of co-mingled contamination in the MW-21D area (i.e., benzene and chlorinated ethenes) suggests that benzene is acting as the electron donor to promote degradation of the chlorinated ethenes (i.e., the electron acceptor). From a natural attenuation perspective, the remaining major concern in the area of MW-21D is the presence of the biologically recalcitrant compound 1,4-dioxane.

The geochemical and concentration data further suggest that the limiting factor in continuing dechlorination in some areas may be that concentrations of chlorinated VOCs have fallen below levels capable of supporting strong communities of dechlorinating organisms (<100 ug/L). Only six (6) out of 28 wells now have total VOC concentrations >100 ug/l, suggesting that many of the wells have reached VOC concentrations that no longer support strong dechlorinating microbial populations. Most wells on-Site have geochemical conditions conducive to reductive dechlorination with the exception of a suitable amount of total organic carbon (TOC). In such instances, for example in the MW-5D/MW-13D area, carbon addition may be effective in enhancing biodegradation.

Overall, the geochemistry data indicate that anaerobic conditions prevail and that multiple terminal electron-acceptor process (TEAPs) are occurring, including iron reduction, sulfate reduction and limited methanogenesis, which are known to support the degradation of chlorinated VOCs. Elevated concentrations of ultimate non-toxic daughter compounds (methane, ethane, and ethene) and intermediate biodegradation products, that in numerous wells exceed the concentrations of parent compounds, show that complete reduction of PCE and TCE, and of chlorinated ethane and chlorinated methane parent compounds is occurring at the Site.

3.0 REMEDIAL ACTION OBJECTIVES

As noted in the preceeding section, the primary contaminants of concern in the groundwater are chlorinated aliphatic hydrocarbons and aromatic hydrocarbons. The primary potential exposure routes to these contaminants are through ingestion, inhalation and dermal contact with extracted deep groundwater by potential future groundwater users. Vapor intrusion is not a concern due to the depth of the contaminated OU-3 groundwater and lack of shallow groundwater contamination outside the slurry wall as noted by USEPA in its recent 5-year review (USEPA, 2008).

Accordingly, preliminary RAOs are as follows:

- Prevent unacceptable exposures to impacted groundwater;
- Control future migration of constituents of concern in groundwater; and,
- Restore groundwater quality to regulatory or risk based levels, as appropriate.

4.0 POTENTIAL REMEDIAL TECHNOLOGIES

The nature and extent of contamination in OU-3 consists of two distinct areas with differing contaminant "signatures":

- Predominantly chlorinated ethene contamination in the vicinity of MW-5D, MW-13D and downgradient areas in the till (see Figure 3), and at lower concentrations in the upper bedrock within a co-located but smaller area compared to the till (see Figure 4); and,
- Predominantly benzene contamination with 1,1 dichloroethane and 1,4 dioxane in the local vicinity of MW-21 D in the till (see Figure 3).

Potential remedial technologies are described below and summarized in Table 1, with specific application to each of the areas noted above. Each technology is evaluated in connection with the differing groundwater conditions in each area; a cleanup method may be appropriate in one area but not in another.

4.1 No Further Action

The National Contingency Plan (NCP) requires that no further action be retained as an alternative through the Feasibility Study. The No Action response establishes the anticipated exposure and risk to public health, welfare, and the environment if no further actions are taken, and provides the baseline to which all other alternatives may be compared. This alternative relies solely on natural processes to reduce the mobility, toxicity, and volume of contaminants.

4.2 Institutional Controls

A Classification Exception Area (CEA) and Well Restriction Area (WRA) established by the New Jersey Department of Environmental Protection (NJDEP) serves as notice that groundwater standards are not met in a localized area, and that designated aquifer uses, including the installation of wells, are suspended in the affected area for the term of the CEA, so as to ensure that potential receptors are protected until standards are achieved. Such institutional controls are effective in preventing future exposure pathways and therefore will be retained for further consideration

4.3 Monitored Natural Attenuation

This technology addresses contaminated groundwater through on-going natural attenuation processes accompanied by rigorous verification monitoring. MNA utilizes natural *in situ* processes including physical, biological or chemical methods that reduce the mass, toxicity, mobility, and volume of chemicals.

As noted in Section 2.4.3, review of geochemical indicator parameters for Site wells indicates that anaerobic conditions prevail and that multiple TEAPs are occurring, including iron reduction, sulfate reduction and limited methanogenesis, all of which are known to coexist with active reductive dechlorination of CAHs. Elevated concentrations of non-toxic daughter compounds (ethane and ethene) and intermediate biodegradation products (cis-DCE), which in numerous wells exceed the concentrations of parent compounds, also show that complete reduction of PCE and TCE and of chlorinated ethane parent compounds is occurring at the Site. Current concentrations of nearly all VOCs in the investigation wells are below historic high concentrations, and, in many cases are substantially less. Given these favorable indicators, MNA will be retained as a potential remedial technology.

4.4 Enhanced Anaerobic Bioremediation

This technology addresses contaminated groundwater by utilizing already active microorganisms in the subsurface and adding additional carbon sources to the system to further stimulate biological degradation. Four primary pathways exist for the biologically mediated degradation of organic compounds: aerobic oxidation, anaerobic oxidation, aerobic cometabolism and anaerobic reductive dechlorination. Success of a particular pathway requires compatible geochemical conditions, appropriate nutrients, contact between contaminant and microorganism and adequate time. For this Site, with moderately anaerobic conditions (ORP +100 to -300), stimulating anaerobic degradation is the most viable pathway.

A significant body of laboratory and field research and applications over the past 10 years has shown that bacteria that naturally exist in the subsurface (indigenous) possess the capability to biodegrade chlorinated ethenes and ethanes to non-chlorinated environmentally acceptable end products such as ethene, ethane and chloride. The biodegradation reactions occur under a wide range of environmental conditions, and by a variety of different bacteria. The VOCs serve as electron acceptors with simple organic carbon compounds (such as fatty acids and alcohols) serving as the electron donors. Many environments can support active reductive dechlorination. However, in most environments the addition of nutrients or electron donors (i.e., biostimulation) can enhance the on-going biological activity. Based on the present natural degradation trends, biostimulation is retained as a potential remedial technology for the MW-5D area and downgradient impacts. Enhanced anaerobic bioremediation is not retained for the MW-21D area as it would not be effective in addressing the biologically recalcitrant 1,4-dioxane.

4.5 In-situ Chemical Reduction (ISCR)

Abiotic dechlorination of contaminants by introduction of zero-valent metals in anoxic groundwater occurs as the zero-valent metal serves as a proton donor (i.e., dechlorinating the organic compound by hydrogen addition). The reaction produces oxidized metal, chloride ions, and hydrogen gas. This reaction occurs relatively quickly by first-order kinetics and zero-valent iron has been used for some time to remediate sites contaminated by chlorinated solvents. This technology can be implemented as a permeable reactive barrier (PRB) or by distribution of the zero valent iron material through injection of nano-scale particles (nZVI) into the subsurface and transport by groundwater flow. Given the highly developed nature of the area surrounding the Property and depth of the required treatment zone, construction of a PRB is not likely to be feasible. With flat hydraulic gradients and limited groundwater flow, delivery of contaminants to a nZVI treatment zone is likely to be slow and heterogeneous. In addition, low permeability sediments may cause additional issues with nano scale particle injection such as well clogging.

Given its demonstrated effectiveness for chlorinated solvents, the nZVI technology has been retained for the MW-5D area and immediate downgradient impacts, but not for the MW-21D area, as it would not be effective in addressing 1,4-dioxane.

4.6 In-situ Chemical Oxidation (ISCO)

In-situ chemical oxidation (ISCO) involves the delivery of chemical oxidants to contaminated media to destroy the contaminants by converting them to innocuous compounds (e.g., CO_2). Typical oxidants applied in this process include hydrogen peroxide (H_2O_2), ozone (O_3), potassium permanganate ($KMnO_4$) and persulfate ($S_2O_8^{2-}$).

Chemicals are stored in tanks on-Site or made on-Site and delivered directly to the groundwater through specially designed injection wells. A considerable volume of chemicals is typically required introduced through frequent repeat injections. Repeat injections are typically necessary with ISCO applications due to the relatively short half-life of ISCO reagents in the subsurface. Redistribution of sorbed contaminants typically occurs on a time-scale that is longer than the half-life of the ISCO reagents, creating the necessity for re-injection. Determining the applicability of the technology requires evaluation of the natural oxidation demand, which must be satisfied with reactants before any oxidation of contaminants will occur This technology is typically effective for localized, high concentration areas of contamination (e.g., the area around MW-21 D and the immediate vicinity of MW-5D) but is not suitable for disperse, low concentration plumes. The relative merits of different oxidants are discussed in the following paragraphs.

Catalyzed Hydrogen Peroxide (CHP)

The most common form of CHP involves Fenton's Reagent where hydrogen peroxide (H_2O_2) is applied with an iron catalyst (ferrous sulfate) creating a hydroxyl free radical. Newer technologies also allow for the generation of free radicals using additional catalysts. The hydroxyl free radical is capable of oxidizing organic compounds and residual hydrogen peroxide decomposes into water and oxygen in the subsurface. The oxidation reaction proceeds with extremely fast, pseudo first-order kinetics. CHP reactions are most effective in systems with acidic pH and so the natural Site conditions (alkaline pH) are not ideal.

Frequent repeat injections are normally necessary due to the high reactivity of hydrogen peroxide and the low peroxide concentration that can safely be injected. This large volume of liquid injected into the aquifer has the potential to hydraulically disperse contamination due to mounding around the injection wells. Oxidation in the subsurface may also result in mobilization of naturally-occurring metals into the groundwater system.

This technology has been retained for the MW-5D area and immediate downgradient impacts and for the MW-21D area due to the potential ability of CHPs to degrade 1,4-dioxane.

Ozone

Ozone gas (O_3) can oxidize contaminants either directly or through the formation of hydroxyl radicals. Like peroxide, ozone reactions are most effective in systems with acidic pH and so the natural Site conditions are not ideal. The oxidation reaction proceeds with extremely fast, pseudo first-order kinetics. Due to ozone's high reactivity and instability, O_3 would need to be produced on-Site, and would require closely spaced delivery points (i.e., sparging wells). Because the ozone is injected as a gas, a large proportion of the gas is generally lost from the aquifer as bubbles migrate to the vadose zone. In-situ decomposition of the ozone can lead to beneficial oxygenation and biostimulation of aerobic bacteria and thus this technology may be paired with aerobic-biodegradation.

The technology has been eliminated as on-Site ozone production is difficult, costly and presents health and safety issues in comparison to other oxidants. In addition, gas transfer limitations cause this technology to be limited to a small radius of influence.

Permanganate

The reaction stoichiometry of permanganate (typically provided as liquid or solid $KMnO_4$, but also available in Na, Ca, or Mg salts) in natural systems is complex. Due to its multiple valence states and mineral forms, Mn can participate in numerous reactants. The reactions proceed at a somewhat slower rate than the previous two reactants, according to second-order kinetics. Depending on pH, the reaction can include destruction by direct electron transfer or free radical advanced oxidation. Permanganate reactions are effective over a pH range of 3.5 to 12 and are, therefore, less sensitive to pH conditions than the previously described reactants. The volume and chemical composition of individual treatments are based on the contaminant concentrations, volume, subsurface characteristics and pilot-scale test results. This technology has been retained for consideration for the MW-5D area and immediate downgradient impacts. However, permanganate has been rejected for the MW-21D area due to its inability to oxidize 1,4-dioxane and benzene.

Sodium Persulfate

The reaction stoichiometry for sodium persulfate (typically provided as a crystalline solid $Na_2S_2O_8$) includes the reduction of persulfate ($S_2O_8^{2-}$) to sulfate (SO_4^{2-}) and the concomitant oxidation of target contaminants. Compared to the previously described oxidants, persulfate may be the most effective oxidant for *in situ* oxidation at this Site given the naturally high alkalinity. The technology has been retained for the MW-5D area and immediate downgradient impacts as well as for the MW-21D area.

4.7 In-Well Re-Circulatory Air Sparging/Stripping

This in-well technology combines *in situ* air stripping, air sparging, soil vapor extraction and enhanced bioremediation/oxidation in a proprietary innovative wellhead system (i.e., the ART system). Groundwater is re-circulated through a dual casing well to enhance air stripping efficacy by allowing multiple passes of a water slug through the treatment system. Air sparging provides elevated oxygen concentrations to groundwater that is recharged into the aquifer, through the development of a radius of aerobic conditions proximal to the treatment well. The system requires treatment of collected vapors and has been reported to effectively treat CAHs, benzene and 1,4-dioxane. The mode of treatment for 1,4 dioxane has been attributed by ART to the multiple treatment passes through the system.

This technology has been retained for consideration for the MW-21D area. Due to a potentially small radius of influence and significant above-grade infrastructure, in-well re-circulatory air-sparging/stripping has been rejected for the MW-5D area and downgradient impacts within developed areas.

4.8 Groundwater Extraction and Treatment

This technology addresses contaminated groundwater through collection, treatment, and discharge (i.e., pump and treat). Several options exist with this technology, including different extraction methods (extraction wells, subsurface drains); different treatment options (Air Stripping, Carbon Adsorption, UV Peroxidation/Ozonation; transfer to a Treatment, Storage and Disposal (TSD) Facility; transfer to Publicly Owned Treatment Works (POTW); and disposal methods for treated groundwater. These options are further described and screened in Table 1.

The application of this technology is limited by the extensive commercial development in the area of the Site, which limits the construction feasibility of the infrastructure necessary to extract and convey groundwater. Furthermore, discharge options for treated groundwater are likely to be limited and costly.

Groundwater extraction and treatment has been retained for the MW-5D area and immediately downgradient impacts and the "hot spot" area in the vicinity of MW-21D. Ex-situ treatment would likely require UV Peroxidation to remove 1,4-dioxane from the area around MW-21D.

5.0 RETAINED REMEDIAL ALTERNATIVES

Based on the screening of remedial technologies discussed in the preceding section and in Table 1, the following alternatives are retained for further evaluation:

1. No Further Action - as required by the National Contingency Plan (NCP).

MW-5D/13D/R and Downgradient Impacts

2. In Situ Anaerobic Biostimulation
3. In-situ Chemical Oxidation (ISCO)
4. In Situ Chemical Reduction (ISCR)
5. Groundwater Extraction and Treatment

MW-21D Area

6. ISCO
7. In-well re-circulatory Air Sparging/stripping
8. "Hot Spot" Groundwater Extraction and Treatment

A common component in all of the above alternatives is the use of Institutional Controls and Monitored Natural Attenuation (MNA) to address residual contaminants.

6.0 PRELIMINARY SCREENING OF ALTERNATIVES

6.1 General

Conceptual designs have been developed to further evaluate potential remedial approaches. Injection-based technologies have been evaluated based on previous experience, geologic and hydrogeologic data and estimated reagent quantities based on current groundwater quality data (Golder, 2007). Extraction technologies have been evaluated based on preliminary capture zone calculations which considered estimated hydraulic gradients and conductivities.

A significant design consideration for any remedial alternative at the Site is the limited access and highly developed (commercial/light industrial) surroundings. As shown in Figures 3 and 4, most of the contaminant plume is under roadways, building footprints, the creek bed or active parking and operating lots. From a contaminant mass standpoint, an active remediation system within the 500 ppb total VOC isoconcentration contour will access approximately 80 percent of the total mass present in the till and approximately 80 percent of the total contaminant mass present in the bedrock. Given these access and plume distribution considerations, the remedial alternatives for the MW-5D/13D/R area focus on actively addressing contaminants within the plume core defined by the 500 ppb total VOC isoconcentration contour, and include MNA to address lower levels of contaminants downgradient.

6.2 Alternatives for MW-5D/13D/R and Downgradient Impacts

In-Situ Anaerobic Biostimulation

The conceptual design of this system includes a series of off-Property injection wells to directly address the contaminant mass present within the 500 ppb total VOC isoconcentration contour. In addition, a series of on-Property injection wells would focus on reducing the source mass present in proximity to MW-5D. Figure 5 illustrates a conceptual arrangement of injection points, based on an estimated radius of influence (ROI) of 20-30 feet. It is anticipated that a minimum of 12 monthly injections would be necessary in the downgradient injection points involving approximately 800 kg of lactate and approximately 500 kg of ethanol, to stimulate the biodegradation of the known levels of impact. Following this initial injection program, a longer-term injection program would be undertaken in the on-Property wells to provide continued source treatment/containment. This injection program would likely use a longer-lasting carbon source, e.g., emulsified vegetable oils.

In-Situ Chemical Oxidation (ISCO)

The conceptual approach for an ISCO remedy includes a series of off-Property injection wells similar to those proposed for the biostimulation alternative as illustrated in Figure 5. Accurate estimation of the frequency and quantity of oxidant required will require bench and/or field studies of soil oxidant demand. ISCO reagents are fast-acting, but not long-lasting in the subsurface so multiple injections are anticipated.

In-Situ Chemical Reduction (ISCR)

The conceptual approach for an ISCR remedy using nano-scale zero-valent iron (nZVI) injection would require the placement of approximately 60 injection wells throughout the plume core area in the same vicinity as the biostimulation injection wells, but with closer spacing (see Figure 5). It is anticipated that a minimum of two (2) phases of injections over one (1) to two (2) years would be necessary to inject approximately 25,000 kg of nZVI so as to degrade the known levels of impact. Further injections would likely be necessary in on-Property wells to address source concentrations. Pilot testing would be necessary to determine the design ROI and injection efficiency. It is anticipated that the injection and distribution of nZVI may be difficult due to the geologic and hydrogeologic conditions present on-Site.

Groundwater Extraction and Treatment

Because of the flat hydraulic gradients in the Site area, the anticipated capture zone of extraction wells is relatively large, even for modest pumping rates. Capture of the plume core area within the 500 ppb total VOC contour may be achievable with as few as two extraction wells. However, completion of the necessary conveyance system within the current developed area and establishing a feasible mechanism for discharge of treated groundwater will be challenging.

6.3 Alternatives for MW-21D Area

In-Situ Chemical Oxidation (ISCO)

The conceptual approach for an ISCO remedy would involve the placement of approximately 16 injection wells in a grid pattern as illustrated in Figure 5. As noted above, accurate estimation of the frequency and quantity of oxidant necessary to treat the impacted area will require bench and/or field studies. However, based on the anticipated size of the treatment zone and known concentrations of contaminants, it is anticipated that ISCO will be a reasonably cost-effective option for this area, and can address 1,4-dioxane, which is recalcitrant by most other methods.

In-Well Re-Circulatory Air Sparging/Stripping

The MW-21D Area "Hot spot" area may be treated using the In-well Re-circulatory method (i.e., ART) that uses a combination of in-situ air stripping, sparging and aerobic biostimulation. Vendor information suggests that this technology can treat all of the contaminant classes, although the mode of action for 1,4 dioxane is unclear. Given the anticipated localized extent of impacts in this area, a single recirculation well treatment system may be adequate.

"Hot Spot" Groundwater Extraction and Treatment

As noted above, the relatively flat hydraulic gradients indicate that a sufficient capture zone may be established using a single extraction well with a modest pumping rate (<5 gpm). Treatment of the extracted groundwater will be complicated by the presence of 1,4 dioxane and discharge options may be limited.

6.4 Retained Site-Wide Alternatives

Table 2 presents a preliminary screening of the above alternatives based on effectiveness, implementability and relative cost, qualitatively ranking the alternatives as low, medium, or high for each criterion. Based on this preliminary evaluation, the following Site-wide alternatives are recommended for detailed analysis:

<u>Alternative A</u>

No Further Action.

<u>Alternative B</u>

In-situ anaerobic biostimulation (MW-5D/13D/13R plume core area) with in-situ chemical oxidation (MW-21D area).

<u>Alternative C</u>

In-situ anaerobic biostimulation (MW-5D/13D/13R plume core area) with in-well recirculatory treatment (MW-21D area).

Alternative D

Groundwater extraction and treatment (MW-5D/13D/13R plume core area and MW-21D area).

Monitored natural attenuation and institutional controls are expected to be common elements that would also be included in each of the above alternatives.

7.0 REFERENCES

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Table 1
Candidate Technology Screening for Groundwater

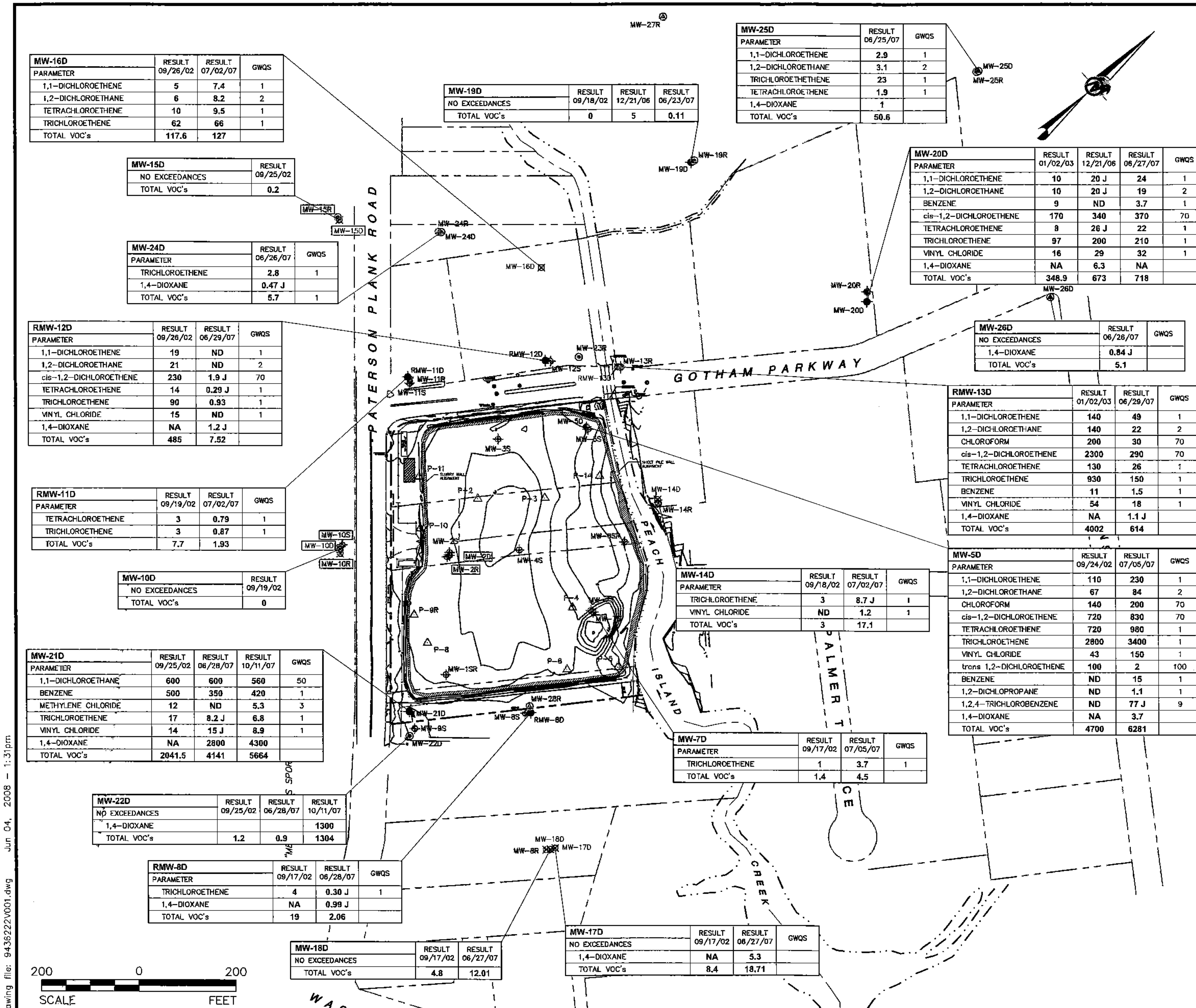
Remedial Technologies	Process Options	Description	Preliminary Screening Comments	Retained or Eliminated
No action	N/A	No action	Required by NCP for analysis during the Feasibility Study	Retained
Institutional Controls	CEA/WRA	Establishment of classification area and a well restriction area to restrict groundwater use in the area of concern in accordance with N.J.A.C. 7:26E (Subchapter 8).	Requires landowner consent, can be protective of human health.	Retained
Monitored Natural Attenuation	Natural Degradation	Naturally occurring chemical, physical and biological degradation is allowed to progress and ongoing monitoring wells (existing or new) are used to assess contaminant remediation in accordance with N.J.A.C. 7:26E-6.3.	**MW-21D Area** – Natural attenuation (NA) assessment observed strong biological degradation (likely due to availability of carbon from benzene); chemical/biological degradation pathway for 1,4-dioxane unlikely.	Retained
			MW-5D and Downgradient Impacts - NA assessment observed on-going biological degradation; low hydraulic gradients and conductivities create slow travel times, increasing the effectiveness of natural processes.	Retained
Enhanced Anaerobic Bioremediation	Biostimulation	Uses indigenous microorganisms and adds carbon sources to stimulate biological activity and enhance biodegradation. There are numerous substrates available for enhancing anaerobic microorganisms.	**MW-21D Area** – NA parameters suggest on-going biological degradation on-site, carbon source addition may intensify already on-going biodegradation of chlorinated ethenes and ethanes, may degrade benzene, will not likely degrade 1,4-dioxane	Eliminated
			MW-5D and Downgradient Impacts – NA parameters suggest on-going biological degradation on-site. Carbon source addition may intensify already on-going biodegradation; can be used to limit the progress of contaminants off-property; hydrologic limitation may exist for injection	Retained
In Situ Chemical Reduction (ISCR)	Zero-Valent Iron (nZVI)	Nano-scale zero valent iron (nZVI) particles are injected into the groundwater or zero-valent iron permeable reactive barrier is constructed and acts as an electron donor in the reductive dechlorination of chlorinated compounds. nZVI may also act to stimulate naturally occurring biodegradation by creating highly anaerobic conditions.	**MW-21D Area** – ZVI will not degrade benzene or 1,4-dioxane.	Eliminated
			MW-5D and Downgradient Impacts - nZVI has been shown to be effective in reductively degrading chlorinated compounds, nZVI also may enhance active anaerobic biodegradation through H_2 production. Construction of a PRB is not feasible at this Site and injection and distribution of nZVI may be difficult due to the hydrologic conditions	Retained
In Situ Chemical Oxidation (ISCO)	Catalyzed Hydrogen Peroxide (CHP)	Hydrogen peroxide (H_2O_2) is applied with or without an iron catalyst (ferrous sulfate) or additional catalysts to create reactive radical species (e.g., OH•). The free radicals are capable of oxidizing organic compounds to CO_2.	**MW-21D Area** – Free radical species are highly reactive and may achieve significant reduction in mass; radical species are capable of degrading 1,4-dioxane	Retained
			MW-5D and Downgradient Impacts - Free radical species are highly reactive and may achieve significant reduction in contaminant mass. Typically effective for localized, high concentration areas of contamination and targeted approach may not achieve coverage of disperse low concentration plume.	Retained
	Ozone	Ozone gas (O_3) can oxidize contaminants either directly or through the formation of hydroxyl radicals. Must be generated on-site and injected in the gas phase.	**MW-21D Area** – On-site production of ozone gas is restrictive; gas influx is restrictive for reactive travel time and distance; does not appear applicable on this site	Eliminated
			MW-5D and Downgradient Impacts - On-site production of ozone gas is restrictive, gas influx is restrictive for reactive travel time and distance, does not appear applicable on this site	Eliminated
	Permanganate	Permanganate (MnO_4^-) is injected as $KMnO_4$ or $NaMnO_4$ and is capable of oxidizing organic compounds. KMnO4 is preferred as injection of sodium can affect permeability through precipitation of sodium salts, Permanganate persists for long periods of time (weeks to months) and is effective in permeable materials, transports greater distances through porous media.	**MW-21D Area** – Not applicable, permanganate is not reactive towards benzene	Eliminated
			MW-5D and Downgradient Impacts – Could be used in specific area to reduce contaminant mass. Typically effective for localized, high concentration areas of contamination and targeted approach may not achieve coverage of disperse low concentration plume. Has longer residence time and can travel in low permeability materials to greater distance than CHPs, reaction product manganese oxide can clog aquifer and decrease permeability	Retained
	Persulfate	Persulfate ($S_2O_8^{2-}$) is injected as $Na_2S_2O_8$ and the reduction of persulfate to sulfate (SO_4^{2-}) is linked to the oxidation of organic compounds. ISCO with persulfate is highly effective with activation which may be achieved with natural alkalinity	**MW-21D Area** – Highly reactive and may achieve significant reduction in mass, radical species are capable of degrading 1,4-dioxane	Retained
			MW-5D and Downgradient Impacts - Could be used in specific areas to reduce mass. Typically effective for localized, high concentration areas of contamination and targeted approach may not achieve coverage of disperse low concentration plume. Has long residence time and can travel in low permeability materials	Retained
In-well re-circulatory Air Sparging/stripping	N/A	In well technology combines in-situ air stripping, air sparging, soil vapor extraction and enhanced bioremediation/oxidation in a wellhead system (i.e., the ART system). Groundwater is re-circulated through a dual casing well design to enhance air stripping efficacy by allowing multiple passes of a water slug through a treatment system, air sparging provides elevated oxygen concentrations to groundwater and creates a gradient towards the well generating aerobic conditions. Requires treatment of collected vapors; has been shown to effectively treat chlorinated compounds, benzene and reportedly 1,4-dioxane (although in this case the mode of action is unclear)	**MW-21D Area** – "Hot spot" area could be treated to remove chlorinated compounds, benzene and possibly 1,4-dioxane	Retained
			MW-5D and Downgradient Impacts – Potentially small area of influence requires extensive well network in a nearby commercial area, not well suited for a disperse, low concentration plume	Eliminated
Groundwater Extraction and Treatment	Collection	Extraction Wells – Installation of a series of wells to extract contaminated groundwater	**MW-21D Area and MW-5D and Downgradient Impacts** – Series of extraction wells could provide hydraulic containment of on-site contamination, could generate hydraulic gradients useful for combined treatment (e.g., bioremediation). Could be used as "hot spot" source removal at MW-21D or hydraulic control at MW-13D and downgradient impacts. Will require access agreements due to commercial area for installation of wells, piping system, and Operation and Maintenance.	Retained

Remedial Technologies	Process Options	Description		Preliminary Screening Comments	Retained or Eliminated
		Subsurface Drains	Perforated pipe installed in trenches and backfilled to collect contaminated water	Not technically feasible due to trenching limitations with deep groundwater (> 50 feet to bedrock).	Eliminated
	Treatment	Air Stripping	VOCs are transferred to the vapor phase and collected for further treatment, not effective for 1,4-dioxane	**MW-21D Area** –Not applicable, does not effectively treat 1,4-dioxane	Eliminated
				MW-5D and Downgradient Impacts - Potentially applicable	Retained
		Carbon Adsorption	Granular activated carbon (GAC) is used to specifically adsorb organic constituents from the groundwater that is passed though, not effective for 1,4-dioxane	**MW-21D Area** – Not applicable, does not effectively treat 1,4-dioxane	Eliminated
				MW-5D and Downgradient Impacts - Potentially applicable	Retained
		UV Peroxidation/Ozonation	Contaminated groundwater is exposed to UV radiation and/or oxidizers (e.g., H_2O_2 or ozone) creating a highly oxidizing environment to degrade organic contaminants, efficient at degrading 1,4-dioxane	**MW-21D Area** – Potentially applicable	Retained
				MW-5D and Downgradient Impacts - Potentially applicable	Retained
	Discharge	Treatment, Storage and Disposal (TSD) Facility	Extracted water shipped off-site to TSD facility for treatment	Potentially applicable; currently OU-2 groundwater is shipped to a TSD, acceptance is likely based on OU-2; larger volumes may make this option cost prohibitive	Retained
		Publicly Owned Treatment Works (POTW)	Extracted water shipped or connected by sewer to local POTW for treatment, may require pretreatment	Potentially applicable; pre-treatment may be necessary depending on POTW requirements	Retained
		Re-Injection	Post-treatment extracted water is discharged into a series of wells or drainage basins	Not applicable; due to already complex hydraulic conditions re-injection may pose further technical issues	Eliminated

Table 2
Preliminary Screening of Remedial Alternatives

Remedial Alternative	Effectiveness	Implementability	Cost
No Further Action	Low – Natural attenuation processes appear to active on-site and may remove significant mass with time, however, low COC concentrations and low organic carbon concentrations may limit natural attenuation in some areas, 1,4-Dioxane in the MW-21D Area will likely not be attenuated naturally	High – requires no additional remedial action for till and bedrock groundwater	Low - requires no additional remedial action for till and bedrock groundwater
MW-5D/13D/13R and downgradient impacts (1)			
In Situ Anaerobic Biostimulation + MNA	High – Evaluation of current natural attenuation of the MW-5D and downgradient impacts suggests that biodegradation is active, low COC concentrations and low organic carbon concentrations may limit natural attenuation in some areas, biostimulation using electron donor injection will overcome this limitation and enhance already active biodegradation	Medium – A series of injection wells could be placed at and immediately downgradient along the northern Site boundary. A minimum of 12 monthly injections are likely necessary to treat this area. Injections in a commercial/light industrial area and along public roads will be difficult.	Medium – Installation of injection wells and injection systems are moderately expensive. Biostimulation reagents (e.g., lactate and ethanol) are relatively inexpensive and due to relatively low concentrations of target compounds the cost for reagents should be relatively low.
In-situ Chemical Oxidation (ISCO) + MNA	Medium – ISCO requires direct contact of oxidant and contaminant and may be hindered by low permeability and a relatively small injection radius of influence, oxidant reacts rapidly in subsurface and limits ROI	Medium – A series of closely spaced injection wells could be placed at and immediately downgradient along the northern Site boundary. Because of the reactive nature of oxidants, ROI is defined both by hydrology and by reactivity. Injections of reactive materials in a commercial/light industrial area and along public roads will be very difficult.	Medium to High – Installation of injection wells and injection systems are moderately expensive. Low concentration plumes tend to be highly cost-inefficient to treat with ISCO.
In Situ Chemical Reduction (ISCR) + MNA	Medium – Injection of nano-particles may be difficult due to low permeability and low flow in till, ROI may be limited	Low – A series of closely spaced injection wells could be placed at and immediately downgradient along the northern Site boundary. Injection of particles into relatively low permeability till will likely be difficult. Small ROI are anticipated. High groundwater sulfate concentrations will consume a significant quantity of nZVI. Injections in a commercial/light industrial area and along public roads will be very difficult.	High – Due to relatively high concentrations of sulfate in Site groundwater, the natural reductant demand is high and will require significant quantities of nZVI
Groundwater Extraction and Treatment + MNA	High – A capture zone encompassing the entire plume core can be achieved with a few wells. Due to relatively flat hydraulic gradients on-Site this will provide significant hydraulic control and limit further plume migration.	Low – Construction of a multi-extraction well and conveyance system in commercial/light industrial area may be difficult. Disposal of treated groundwater may be problematic.	Medium to High – Construction costs may be significant in a commercial/light industrial area and treatment/disposal costs could be prohibitive.
MW-21D Area (1)			
ISCO	High – With a smaller area of impact, ISCO delivery can be achieved in the MW-21D Area, ISCO is capable of degrading 1,4 Dioxane	High – A grid of injection points could successfully treat this relatively small area	Low to Medium – Due to the smaller aerial extent of impact in this area, reagent costs should remain modest although natural oxidant demand may increase costs. Installation of injection wells will be a more significant cost.
In-well re-circulatory Air Sparging/stripping	Medium – In-well re-circulation should be an effective means of treatment of benzene, however, effective treatment of 1,4-dioxane is still speculative.	Medium – Installation of re-circulatory well(s) along with a vapor treatment system would be mostly on property.	Low to Medium – May only require one well and a small treatment system. Recirculation would address issues related to disposal of treated groundwater.
"Hot Spot" Groundwater Extraction and Treatment	Medium – A low pumping rate is expected to achieve capture and contaminants can be treated ex-situ.	Low-Medium – Installation of an extraction well and a relatively small treatment system is feasible. Disposal of treated groundwater may be problematic.	Medium to High – Treatment system would need to address 1,4-Dioxane. Costs to dispose of treated groundwater may be very high.

Note:
(1) Institutional Controls (CEA and WRA) and monitored natural attenuation to address residual contaminants are common components in all the above remedial alternatives.



MW-16D PARAMETER	RESULT 09/26/02	RESULT 07/02/07	GWQS
1,1–DICHLOROETHENE	5	7.4	1
1,2–DICHLOROETHANE	6	8.2	2
TETRACHLOROETHENE	10	9.5	1
TRICHLOROETHENE	62	66	1
TOTAL VOC's	117.6	127	

MW-15D	RESULT 09/25/02
NO EXCEEDANCES	
TOTAL VOC's	0.2

MW-24D PARAMETER	RESULT 06/26/07	GWQS
TRICHLOROETHENE	2.8	1
1,4–DIOXANE	0.47 J	
TOTAL VOC's	5.7	1

RMW-12D PARAMETER	RESULT 09/26/02	RESULT 06/29/07	GWQS
1,1–DICHLOROETHENE	19	ND	1
1,2–DICHLOROETHANE	21	ND	2
cis–1,2–DICHLOROETHENE	230	1.9 J	70
TETRACHLOROETHENE	14	0.29 J	1
TRICHLOROETHENE	90	0.93	1
VINYL CHLORIDE	15	ND	1
1,4–DIOXANE	NA	1.2 J	
TOTAL VOC's	485	7.52	

RMW-11D PARAMETER	RESULT 09/19/02	RESULT 07/02/07	GWQS
TETRACHLOROETHENE	3	0.79	1
TRICHLOROETHENE	3	0.87	1
TOTAL VOC's	7.7	1.93	

MW-10D	RESULT 09/19/02
NO EXCEEDANCES	
TOTAL VOC's	0

MW-21D PARAMETER	RESULT 09/25/02	RESULT 06/28/07	RESULT 10/11/07	GWQS
1,1–DICHLOROETHANE	600	600	560	50
BENZENE	500	350	420	1
METHYLENE CHLORIDE	12	ND	5.3	3
TRICHLOROETHENE	17	8.2 J	6.8	1
VINYL CHLORIDE	14	15 J	8.9	1
1,4–DIOXANE	NA	2800	4300	
TOTAL VOC's	2041.5	4141	5664	

MW-22D	RESULT 09/25/02	RESULT 06/28/07	RESULT 10/11/07
NO EXCEEDANCES			
1,4–DIOXANE			1300
TOTAL VOC's	1.2	0.9	1304

RMW-8D PARAMETER	RESULT 09/17/02	RESULT 06/28/07	GWQS
TRICHLOROETHENE	4	0.30 J	1
1,4–DIOXANE	NA	0.99 J	
TOTAL VOC's	19	2.06	

MW-18D	RESULT 09/17/02	RESULT 06/27/07
NO EXCEEDANCES		
TOTAL VOC's	4.8	12.01

MW-19D	RESULT 09/18/02	RESULT 12/21/06	RESULT 06/23/07
NO EXCEEDANCES			
TOTAL VOC's	0	5	0.11

MW-25D PARAMETER	RESULT 06/25/07	GWQS
1,1–DICHLOROETHENE	2.9	1
1,2–DICHLOROETHANE	3.1	2
TRICHLOROETHETHENE	23	1
TETRACHLOROETHENE	1.9	1
1,4–DIOXANE	1	
TOTAL VOC's	50.6	

MW-20D PARAMETER	RESULT 01/02/03	RESULT 12/21/06	RESULT 06/27/07	GWQS
1,1–DICHLOROETHENE	10	20 J	24	1
1,2–DICHLOROETHANE	10	20 J	19	2
BENZENE	9	ND	3.7	1
cis–1,2–DICHLOROETHENE	170	340	370	70
TETRACHLOROETHENE	8	26 J	22	1
TRICHLOROETHENE	97	200	210	1
VINYL CHLORIDE	16	29	32	1
1,4–DIOXANE	NA	6.3	NA	
TOTAL VOC's	348.9	673	718	

MW-26D	RESULT 06/26/07	GWQS
NO EXCEEDANCES		
1,4–DIOXANE	0.84 J	
TOTAL VOC's	5.1	

RMW-13D PARAMETER	RESULT 01/02/03	RESULT 06/29/07	GWQS
1,1–DICHLOROETHENE	140	49	1
1,2–DICHLOROETHANE	140	22	2
CHLOROFORM	200	30	70
cis–1,2–DICHLOROETHENE	2300	290	70
TETRACHLOROETHENE	130	26	1
TRICHLOROETHENE	930	150	1
BENZENE	11	1.5	1
VINYL CHLORIDE	54	18	1
1,4–DIOXANE	NA	1.1 J	
TOTAL VOC's	4002	614	

MW-5D PARAMETER	RESULT 09/24/02	RESULT 07/05/07	GWQS
1,1–DICHLOROETHENE	110	230	1
1,2–DICHLOROETHANE	67	84	2
CHLOROFORM	140	200	70
cis–1,2–DICHLOROETHENE	720	830	70
TETRACHLOROETHENE	720	980	1
TRICHLOROETHENE	2800	3400	1
VINYL CHLORIDE	43	150	1
trans 1,2–DICHLOROETHENE	100	2	100
BENZENE	ND	15	1
1,2–DICHLOPROPANE	ND	1.1	1
1,2,4–TRICHLOROBENZENE	ND	77 J	9
1,4–DIOXANE	NA	3.7	
TOTAL VOC's	4700	6281	

MW-14D PARAMETER	RESULT 09/18/02	RESULT 07/02/07	GWQS
TRICHLOROETHENE	3	8.7 J	1
VINYL CHLORIDE	ND	1.2	1
TOTAL VOC's	3	17.1	

MW-7D PARAMETER	RESULT 09/17/02	RESULT 07/05/07	GWQS
TRICHLOROETHENE	1	3.7	1
TOTAL VOC's	1.4	4.5	

MW-17D	RESULT 09/17/02	RESULT 06/27/07	GWQS
NO EXCEEDANCES			
1,4–DIOXANE	NA	5.3	
TOTAL VOC's	8.4	18.71	

LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION –JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – NOVEMBER 2002)
MW-25D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – 2007)
P-4	SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	SITE PROPERTY-BOUNDARY
	PROPERTY/RIGHT-OF-WAY BOUNDARIES
	CONTOUR LINE
	STREAM
	FENCE
	UTILITY POLE
	APPROXIMATE SLURRY WALL ALIGNMENT
	APPROXIMATE SHEET PILE WALL ALIGNMENT

NOTES

1.) COORDINATE SYSTEM SHOWN IS NEW JERSEY STATE PLANE NAD27. ELEVATIONS SHOWN ARE BASED UPON THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD 1929).

2.) GROUNDWATER QUALITY STANDARDS BASED ON "NEW JERSEY REGISTER" N.J.A.C. 7:9–6 "GROUNDWATER STANDARDS" JANUARY 7, 1993 (UPDATED AUGUST 24, 2007).

3.) ALL VALUES REPORTED IN PARTS PER BILLION (ppb).

4.) VALUES INDICATED AS TOTAL VOC's INCLUDE ADDITIONAL CONSTITUENTS FOR WHICH MEASURED LEVELS DID NOT EXCEED THE GROUNDWATER QUALITY STANDARD.

5.) NA – NOT ANALYZED

REFERENCES

1.) TOPOGRAPHIC DATA AND SURFACE FEATURES BASED ON INFORMATION BY TAYLOR, WISEMAN & TAYLOR CONSULTING ENGINEERS / SURVEYORS / PLANNERS / LANDSCAPE ARCHITECTS, MOUNT LAUREL, NEW JERSEY, DATED JUNE 12, 1992.

2.) LOT AND BLOCK DATA FROM LOCAL TAX MAP, BOUNDARIES APPROXIMATE.

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

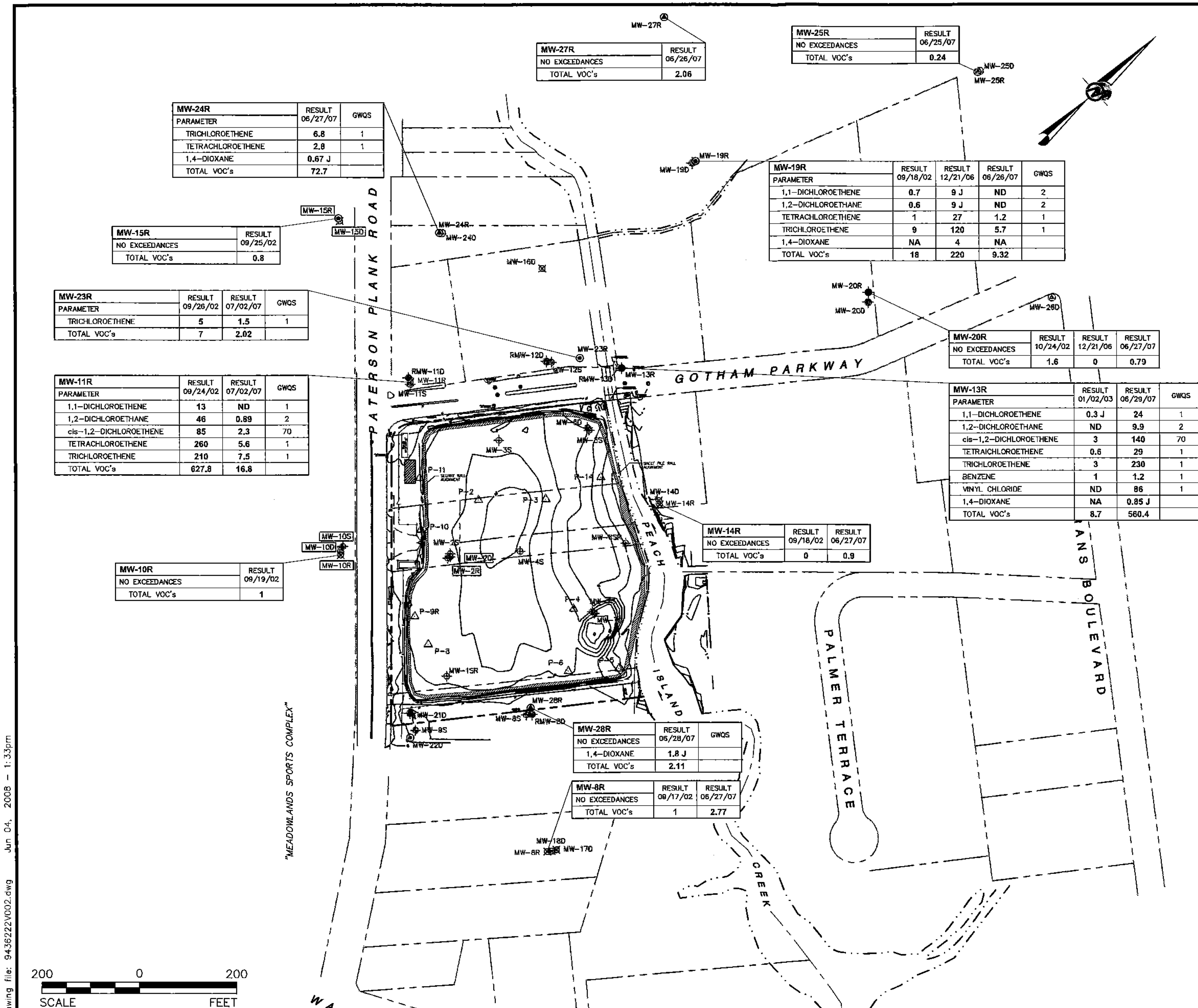
TITLE

TILL GROUNDWATER QUALITY

Golder Associates
Philadelphia USA

PROJECT No.		943–6222	FILE No. 9436222V001	
DESIGN	MJB	06/04/08	SCALE AS SHOWN	REV. 0
CADD	RG	06/04/08	FIGURE 1	
CHECK	MJB	06/04/08		
REVIEW	RJI	06/04/08		

Drawing file: 9436222V001.dwg Jun 04, 2008 – 1:31pm



MW-24R PARAMETER	RESULT 06/27/07	GWQS
TRICHLOROETHENE	6.8	1
TETRACHLOROETHENE	2.8	1
1,4-DIOXANE	0.67 J	
TOTAL VOC's	72.7	

MW-27R NO EXCEEDANCES	RESULT 06/26/07
TOTAL VOC's	2.06

MW-25R NO EXCEEDANCES	RESULT 06/25/07
TOTAL VOC's	0.24

MW-15R NO EXCEEDANCES	RESULT 09/25/02
TOTAL VOC's	0.8

MW-19R PARAMETER	RESULT 09/18/02	RESULT 12/21/06	RESULT 06/26/07	GWQS
1,1-DICHLOROETHENE	0.7	9 J	ND	2
1,2-DICHLOROETHANE	0.6	9 J	ND	2
TETRACHLOROETHENE	1	27	1.2	1
TRICHLOROETHENE	9	120	5.7	1
1,4-DIOXANE	NA	4	NA	
TOTAL VOC's	18	220	9.32	

MW-23R PARAMETER	RESULT 09/26/02	RESULT 07/02/07	GWQS
TRICHLOROETHENE	5	1.5	1
TOTAL VOC's	7	2.02	

MW-20R NO EXCEEDANCES	RESULT 10/24/02	RESULT 12/21/06	RESULT 06/27/07
TOTAL VOC's	1.6	0	0.79

MW-11R PARAMETER	RESULT 09/24/02	RESULT 07/02/07	GWQS
1,1-DICHLOROETHENE	13	ND	1
1,2-DICHLOROETHANE	46	0.89	2
cis-1,2-DICHLOROETHENE	85	2.3	70
TETRACHLOROETHENE	260	5.6	1
TRICHLOROETHENE	210	7.5	1
TOTAL VOC's	627.8	16.8	

MW-13R PARAMETER	RESULT 01/02/03	RESULT 06/29/07	GWQS
1,1-DICHLOROETHENE	0.3 J	24	1
1,2-DICHLOROETHANE	ND	9.9	2
cis-1,2-DICHLOROETHENE	3	140	70
TETRAICHLOROETHENE	0.6	29	1
TRICHLOROETHENE	3	230	1
BENZENE	1	1.2	1
VINYL CHLORIDE	ND	86	1
1,4-DIOXANE	NA	0.85 J	
TOTAL VOC's	8.7	560.4	

MW-14R NO EXCEEDANCES	RESULT 09/18/02	RESULT 06/27/07
TOTAL VOC's	0	0.9

MW-10R NO EXCEEDANCES	RESULT 09/19/02
TOTAL VOC's	1

MW-28R NO EXCEEDANCES	RESULT 06/28/07	GWQS
1,4-DIOXANE	1.8 J	
TOTAL VOC's	2.11	

MW-8R NO EXCEEDANCES	RESULT 09/17/02	RESULT 06/27/07
TOTAL VOC's	1	2.77

LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION -JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - NOVEMBER 2002)
MW-25D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - 2007)
P-4	SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	SITE PROPERTY-BOUNDARY
	PROPERTY/RIGHT-OF-WAY BOUNDARIES
	CONTOUR LINE
	STREAM
	FENCE
	UTILITY POLE
	APPROXIMATE SLURRY WALL ALIGNMENT
	APPROXIMATE SHEET PILE WALL ALIGNMENT

NOTES

1.) COORDINATE SYSTEM SHOWN IS NEW JERSEY STATE PLANE NAD27. ELEVATIONS SHOWN ARE BASED UPON THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD 1929).

2.) GROUNDWATER QUALITY STANDARDS BASED ON "NEW JERSEY REGISTER" N.J.A.C. 7:9-6 "GROUNDWATER STANDARDS" JANUARY 7, 1993 (UPDATED AUGUST 24, 2007).

3.) ALL VALUES REPORTED IN PARTS PER BILLION (ppb).

4.) VALUES INDICATED AS TOTAL VOC's INCLUDE ADDITIONAL CONSTITUENTS FOR WHICH MEASURED LEVELS DID NOT EXCEED THE GROUNDWATER QUALITY STANDARD.

5.) NA - NOT ANALYZED

REFERENCES

1.) TOPOGRAPHIC DATA AND SURFACE FEATURES BASED ON INFORMATION BY TAYLOR, WISEMAN & TAYLOR CONSULTING ENGINEERS / SURVEYORS / PLANNERS / LANDSCAPE ARCHITECTS, MOUNT LAUREL, NEW JERSEY, DATED JUNE 12, 1992.

2.) LOT AND BLOCK DATA FROM LOCAL TAX MAP, BOUNDARIES APPROXIMATE.

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

BEDROCK GROUNDWATER QUALITY

Golder Associates
Philadelphia USA

PROJECT No.		943-6222	FILE No.	9436222V002
DESIGN	MJB	06/04/08	SCALE AS SHOWN	REV. 0
CADD	RG	06/04/08		
CHECK	MJB	06/04/08		
REVIEW	RJI	06/04/08		

FIGURE 2

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LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – NOVEMBER 2002)
MW-25D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – 2007)
P-4	SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	PROPERTY BOUNDARY
	2007 TOTAL VOC ISOCONCENTRATION CONTOUR
	2002 TOTAL VOC ISOCONCENTRATION CONTOUR (SEE NOTE 1)

NOTE

1.) 2002 CONTOURS IN MW-21D NOT PRESENTED AS 1,4-DIOXANE WAS NOT TESTED AT THAT TIME.

REFERENCES

1.) BASE MAP SHOWN TAKEN FROM DIGITAL FILE 3074-02-TOPO.DWG, ENTITLED "BOROUGH OF CARLSTADT BLOCK 124 LOTS 1 THROUGH 5," DATED DECEMBER 8, 2005, PREPARED BY PROMAPS.

2.) HORIZONTAL DATUM REFERENCES THE NEW JERSEY STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83). VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

200 0 200
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

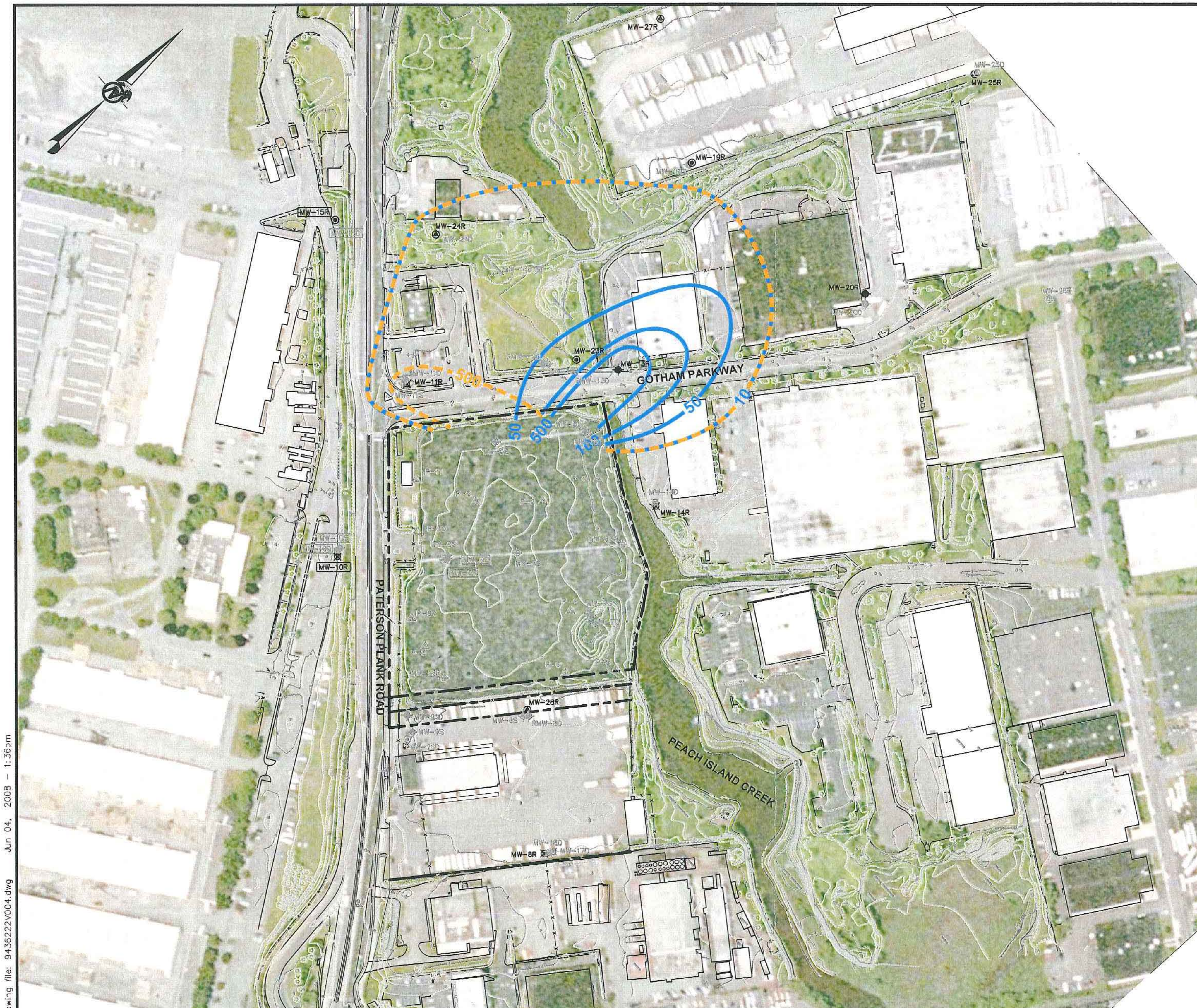
TILL TOTAL VOC ISOCONCENTRATION CONTOURS

Golder Associates
Philadelphia USA

PROJECT No.		943-6222	FILE No.	9436222V003
DESIGN	MJB	06/04/08	SCALE AS SHOWN	REV. 0
CADD	RG	06/04/08		
CHECK	MJB	06/04/08	**FIGURE 3**	
REVIEW	RJI	06/04/08		

Drawing file: 9436222V003.dwg Jun 04, 2008 - 1:35pm

R2-0000673



LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION –JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – NOVEMBER 2002)
MW-25D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – 2007)
P-4	SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	PROPERTY BOUNDARY
	2007 TOTAL VOC ISOCONCENTRATION CONTOUR (SEE NOTE 1)
	2002 TOTAL VOC ISOCONCENTRATION CONTOUR

NOTE

1.) 55 ug/L OF ACETONE DETECTED IN MW-24R NOT INCLUDED IN CONTOURING.

REFERENCES

1.) BASE MAP SHOWN TAKEN FROM DIGITAL FILE 3074-02-TOPO.DWG, ENTITLED "BOROUGH OF CARLSTADT BLOCK 124 LOTS 1 THROUGH 5," DATED DECEMBER 8, 2005, PREPARED BY PROMAPS.

2.) HORIZONTAL DATUM REFERENCES THE NEW JERSEY STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83). VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

200 0 200

SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

BEDROCK TOTAL VOC ISOCONCENTRATION CONTOURS

NJ Authorization #24GA28029100

Golder Associates
Philadelphia USA

PROJECT No.	943-6222		FILE No.	9436222V004
DESIGN	MJB	06/04/08	SCALE AS SHOWN	REV. 0
CADD	RG	06/04/08		
CHECK	MJB	06/04/08	FIGURE 4	
REVIEW	RJI	06/04/08		

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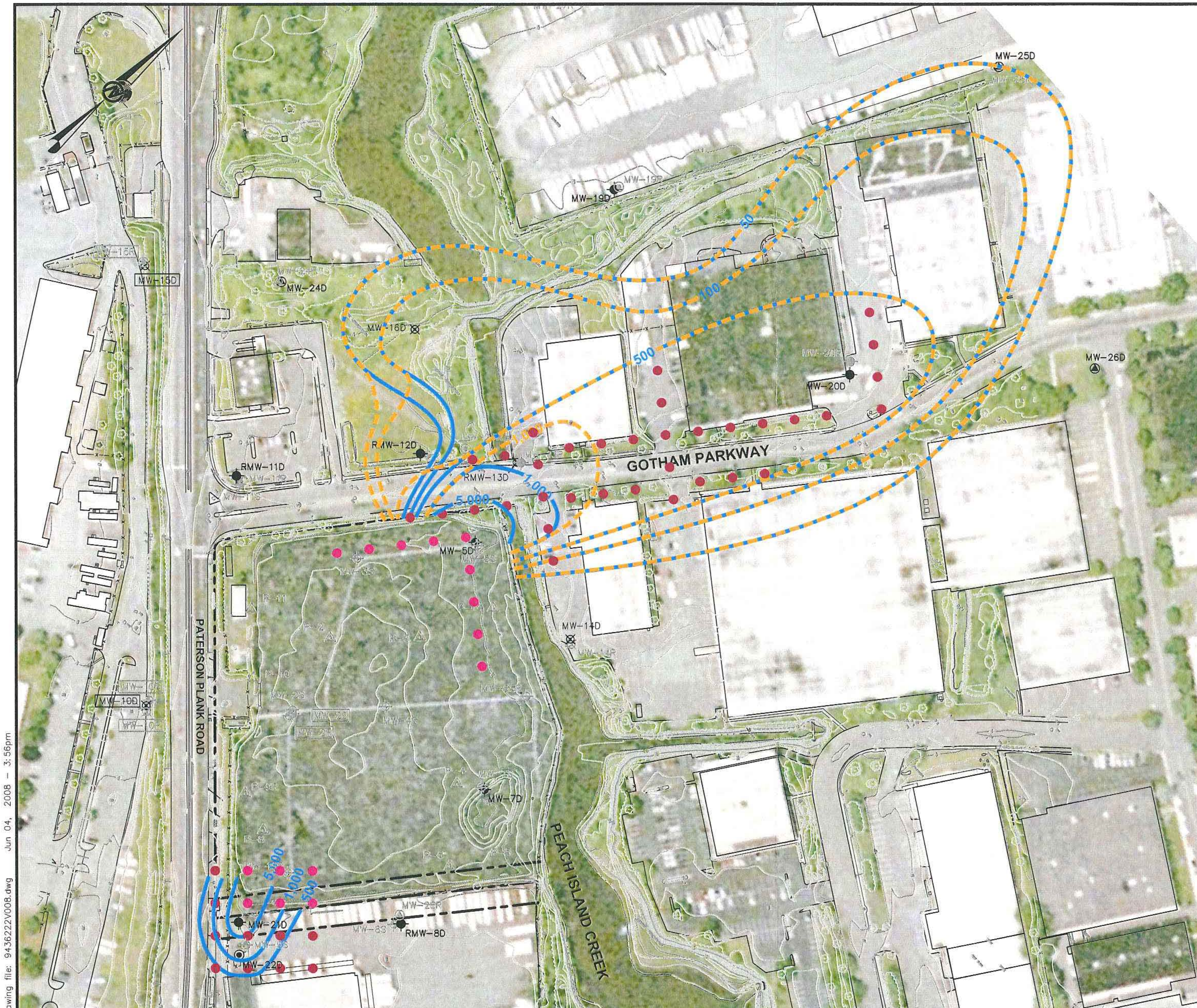

LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION -JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - NOVEMBER 2002)
MW-26D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - 2007)
P-4	SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	POTENTIAL OFF PROPERTY INJECTION WELL
	POTENTIAL ON PROPERTY INJECTION WELL
	PROPERTY BOUNDARY
	2007 TOTAL VOC ISOCONCENTRATION CONTOUR (TILL)
	2002 TOTAL VOC ISOCONCENTRATION CONTOUR (TILL)

REFERENCES

1.) BASE MAP SHOWN TAKEN FROM DIGITAL FILE 3074-02-TOPO.DWG, ENTITLED "BOROUGH OF CARLSTADT BLOCK 124 LOTS 1 THROUGH 5," DATED DECEMBER 8, 2005, PREPARED BY PROMAPS.

2.) HORIZONTAL DATUM REFERENCES THE NEW JERSEY STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83). VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

150 0 150
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT
216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE
CONCEPTUAL ARRANGEMENT OF INJECTION POINTS FOR IN-SITU TECHNOLOGIES

Golder Associates
Philadelphia USA

NJ Authorization #24GA28029100

PROJECT No.	943-6222		FILE No.	9436222V008
DESIGN	MJB	06/04/08	SCALE AS SHOWN	REV. 0
CADD	RG	06/04/08		
CHECK	MJB	06/04/08	FIGURE 5	
REVIEW	RJI	06/04/08		

Drawing file: 9436222V008.dwg Jun 04, 2008 - 3:56pm